Who’s in Charge? Commander, Air Force Forces or Air Force Commander?

Lt Col Brian W. McLean, USAF, Retired

“I’ve got the stick.”
“I’ve got the conn.”
“Sir, I accept command.”

Sometimes different words, appropriate at different levels, all say the same thing. Let’s imagine that you are now in control (of the aircraft, the ship, or the unit) and have both the authority and responsibility that go with the position. But exactly what (or whom) do you have authority over and responsibility for? What is the extent of your authority? Of your responsibility? To whom are you responsible for the consequences of your decisions and actions? A new commander must be able to answer these essential questions. On the surface, the answers might appear simple and obvious, but in practice many people have found that what they think they understand doesn’t reflect the real meaning.

The Fall 1998 edition of Airpower Journal included Brig Gen John Barry’s article “Who's in Charge? Service Administrative Control”—an excellent overview of the role and authority of an Air Force commander as we understood the position at that time. In the 15 years since the appearance of that article, Airmen have gained much better comprehension of the command of Air Force forces (AFFOR), especially with the help of publications such as Air Force Doctrine Document (AFDD) 1, Air Force Basic Doctrine, Organization, and Command; the Air Force Forces Command and Control Enabling Concept and its implementing program action directives; and practical experience in Op-
erations Enduring Freedom and Iraqi Freedom. As General Barry foresaw, “Command authority has once again become a serious subject of discussion . . . in light of the multiple contingency taskings our Air Force has responded to.” It is appropriate to revisit the issues raised by the general in light of our experiences since fall 1998. Discussion of the command and control of AFFOR, especially in deployed operations, first requires a common understanding of three critical terms: *Air Force commander; commander, Air Force forces;* and *chain of command.*

### Air Force Commander

*The beginning of wisdom is calling things by their right names.*

—Confucius

It is important to distinguish between an Air Force commander and a commander, Air Force forces (COMAFFOR). They are not necessarily synonymous titles. The former refers to any Air Force commander within a service context. The latter is reserved exclusively for the senior Air Force commander directly responsible to a joint force commander (JFC) within a joint context. Just as all tigers are cats, but not all cats are tigers, so is every COMAFFOR an Air Force commander, but not every Air Force commander is a COMAFFOR.

What is an Air Force commander? Interestingly, neither Air Force nor joint doctrine includes an official definition of the general term *commander*. Rather, definitions refer to a specific level of position of commander (e.g., JFC, service component commander, joint force air component commander). We find the best official description of a commander in Air Force Instruction (AFI) 38-101, *Air Force Organization*: “an officer who occupies a position of command pursuant to orders of appointment or by assumption of command according to AFI 51-604.” AFI 51-604, *Appointment to and Assumption of Command*, and AFI 38-101 go into the particulars regarding the various levels and types of Air Force units for which a commander may be designated, but neither
provides more details about or a definition of an Air Force commander. From the available description, however, we may conclude that an Air Force commander is an Air Force officer in charge of any Air Force unit or organization. All Air Force commanders are cats.

**Commander, Air Force Forces**

A COMAFFOR, though, is a different animal. Let’s start with the basic definition: “The title of COMAFFOR is reserved exclusively to the single Air Force commander of an Air Force Service component assigned or attached to a JFC at the unified combatant command, sub-unified combatant command, or joint task force (JTF) level.” Three critical terms are embedded in this definition: *joint force, joint force commander, and service component command.*

- A joint force is one composed of significant elements, assigned or attached, of two or more Military Departments, operating under a single JFC.
- Joint force commander. A general term applied to a combatant commander, subunified commander, or [JTF] commander authorized to exercise combatant command (command authority) or operational control [OPCON] over a joint force.
- Service component command. A command consisting of the Service component commander and all those Service forces, such as individuals, units, detachments, organizations, and installations under that command, including the support forces that have been assigned to a combatant command or further assigned to a subordinate unified command or joint task force.

According to joint doctrine, for every level of joint force that has AF-FOR assigned or attached to it, there exists an Air Force service component command. Joint Publication (JP) 1, *Doctrine for the Armed Forces of the United States,* notes that “all joint forces include Service components, because administrative and logistic support for joint forces are provided through Service components.” The commander of the Air Force service component command is the COMAFFOR.
From these interrelated definitions, we can determine four key elements of a COMAFFOR:

1. The position of the COMAFFOR and its associated authorities and responsibilities apply only within the context of an organized joint force.

2. The COMAFFOR is the US Air Force service component commander within that joint force and presents the single Air Force voice to the JFC.

3. The JFC normally delegates OPCON (the authority to organize commands and forces and employ those forces to accomplish the assigned mission—in colloquial terms, the authority to put forces in harm's way) over all assigned or attached AF-FOR within that joint force to the COMAFFOR.

4. No Air Force commander intervenes between a COMAFFOR and the JFC to whom that COMAFFOR is assigned or attached.

**Chain of Command**

The third point for potential confusion comes in the description of the chain of command as well as the commander's authorities and responsibilities within that chain. Even the term *chain of command* promotes uncertainty. Use of the singular noun *chain* implies that it is a single line stretching from the commander in chief to the most junior Airman in the field. But as described in joint and service doctrine, the chain of command actually includes two separate but interrelated branches—the operational and the administrative (see the figure on the next page). The operational branch (in purple) runs from the president through the secretary of defense to the commanders of combatant commands and then to the Air Force service component commanders. The administrative branch (in blue) runs from the president through the secretary of defense to the service secretaries and then—to the extent determined by the service secretary or allowed by law—
through the service chiefs to the service forces. The two branches diverge at the secretary of defense and then reconverge at the Air Force service component commander, the most senior Air Force commander immediately subordinate to the JFC.

Figure. Air Force forces within the chain of command. (Derived from Air Force Doctrine Document 1, Air Force Basic Doctrine, Organization, and Command, 14 October 2011, 89, fig. 7.1, http://static.e-publishing.af.mil/production/1/af_cv/publication/afdd1/afdd1.pdf; and Joint Publication 1, Doctrine for the Armed Forces of the United States, 25 March 2013, II-10, fig. II-3; IV-3, fig. IV-1; IV-6, fig. IV-2; IV-10, fig. IV-4; IV-11, fig. IV-5, http://www.dtic.mil/doctrine/new_pubs/jp1.pdf.)

**The Chain of Command for an Air Force Commander**

Determining the chain of command for an Air Force commander depends upon the color of the hat worn by the next-senior commander...
above. If that commander wears a purple hat, then the Air Force commander responds to both a joint and an Air Force chain of command. Within the joint structure, the Air Force commander is under a combatant commander and possibly either a subunified combatant commander or a JTF commander. Furthermore, as previously discussed, an Air Force commander whose next senior commander wears a purple hat is the COMAFFOR.

The COMAFFOR commands the AFFOR, defined by the *Air Force Forces Command and Control Enabling Concept* as the “USAF component assigned to a [JFC] at the unified, subunified, or Joint [JTF] level. AFFOR includes the COMAFFOR, the AFFOR staff (A-staff/personal staff), the [air and space operations center], and all USAF forces and personnel assigned or attached.”¹² Neither the program action directive nor Air Force doctrine offers further definition or modification to that of the *Enabling Concept*. Instead, Air Force doctrine relies upon the previously cited joint definition of a service component: “A command consisting of the Service component commander and all those Service forces, such as individuals, units, detachments, organizations, and installations under that command, including the support forces that have been assigned to a combatant command or further assigned to a subordinate unified command or joint task force.”

Depending upon the specific joint force involved, the AFFOR may be either permanent units (numbered air force / wing / group / squadron) or expeditionary (numbered expeditionary air force / air expeditionary wing / air expeditionary group / air expeditionary squadron) or some mixture of both. Note that nothing in the Air Force or joint description of the COMAFFOR mentions aircraft. The COMAFFOR is the senior Air Force commander over all AFFOR, including the people, installations, and organizations assigned or attached to a JFC, whether or not those organizations include aircraft.

As shown in the figure, the chain of command above the COMAFFOR flows from both the separate operational and administrative branches so that, in effect, the COMAFFOR answers to two masters. Within the
operational branch, the COMAFFOR is subordinate to the JFC (a purple hat). Within the administrative branch, the COMAFFOR is subordinate to the next-superior Air Force commander (a blue hat). Thus, the COMAFFOR could be in a potentially awkward position if the orders coming from his or her operational-branch JFC conflict with those from the administrative-branch Air Force commander. In that case, the administrative-branch authority is subject to the operational-branch authority, and the JFC’s orders take precedence.  

For AFFOR below the COMAFFOR, the next-senior commander wears a blue hat, and the issue is less challenging. Since the two branches merge at the COMAFFOR, the chain of command for AFFOR below the COMAFFOR (including subordinate Air Force commanders) comes from a single point. Whether subordinate AFFOR commanders employ forces (operational branch) or prepare them for employment (administrative branch), the source of the authority for both branches comes from the COMAFFOR. In terms of a joint force, the COMAFFOR is part of that chain of command and is the senior Air Force commander within the joint force. This arrangement, which provides unity of command for AFFOR responding to orders from both the joint operational branch and the service administrative branch, is the critical link to unity of command.

For AFFOR not assigned or attached to a JFC (e.g., Air Force Material Command and Air Education and Training Command forces or Air Combat Command forces not deployed or attached to a JFC for contingency operations), the situation is even simpler. In these circumstances, there is no purple-hat commander and no COMAFFOR—only an increasingly senior series of Air Force commanders. In these cases, the operational branch of the chain of command does not exist. The Air Force commander in these circumstances remains under the administrative branch of the chain of command only and exercises administrative control (ADCON) as delegated from his or her Air Force senior commander.
The Authorities of an Air Force Commander

Which authority does the Air Force commander need? Well, it depends upon what that commander is tasked to do. Will he or she order forces into harm's way? If so, then the commander needs operational branch authority of either OPCON or tactical control. As described in JP 1, these include

- authoritatively directing all military operations and joint training;
- organizing and employing commands and forces;
- assigning command functions to subordinates;
- establishing plans and requirements for intelligence, surveillance, and reconnaissance activities;
- suspending subordinate commanders from duty; and
- providing local direction and control of movements or maneuvers to carry out the mission.15

For force employment, the COMAFFOR supplies this operational branch authority for all subordinate Air Force units through the exercise of OPCON as delegated from the JFC (purple hat). Normally, the COMAFFOR will retain OPCON at his or her level. However, depending upon the operational circumstances and mission requirements, the COMAFFOR does have the authority to further delegate all or some portion of OPCON to a subordinate Air Force commander. Therefore, as the service component commander to a JFC, the COMAFFOR is responsible for employing the Air Force component in response to the JFC’s orders.

But what if an Air Force commander is preparing forces in accordance with Air Force standards to go into harm's way? Even when this occurs in response to OPCON (e.g., a mission rehearsal or joint exercise prior to deployment), an Air Force commander exercises ADCON to provide properly equipped, manned, and trained AFFOR for tasked missions and functions. With this blue hat and ADCON, the COMAFFOR ensures the Air Force component's proper organization, training,
equipment, and sustainment for employment. Again referring to JP 1, AFDD 1, and AFI 51-604, we see that the authorities of ADCON include

- administration and support responsibilities identified in Title 10, *United States Code*,
- organization of service forces,
- control of resources and equipment,
- personnel management,
- logistics,
- individual and unit training,
- readiness,
- mobilization and demobilization, and
- discipline.\(^{16}\)

The figure above shows that the COMAFFOR, as the service component commander, also exercises service ADCON over all assigned or attached AFFOR. ADCON, the authority necessary to fulfill military department responsibilities for administration and support, runs from the president through the secretary of defense to the secretary of the Air Force. To the degree established by the latter or specified in law, this authority then runs through the chief of staff of the Air Force to the Air Force service component commanders assigned to the combatant commanders and to the commanders of forces not assigned to the combatant commanders. ADCON is not a war-fighting authority in the sense that it does not include the authority to direct military operations. However, it remains critically important to a war fighter since a commander cannot employ forces unless they have been properly prepared and sustained for the tasks they will perform.

As mentioned previously, the operational branch takes precedence over the administrative branch. For example, arranging the service organizational structure to meet operational mission requirements would normally be a responsibility of the service administrative
branch carried out solely under ADCON. However, the operational branch's authority of OPCON does include the authority to “prescribe the chain of command to the commands and forces within the command.” Consequently, with OPCON a JFC may direct the reorganization of assigned and attached AFFOR even if doing so is not in accordance with Air Force standard practice. JP 1 also asserts, however, that such change should occur in consideration of service input: “With due consideration for unique Service organizational structures and their specific support requirements, organize subordinate commands and forces within the command as necessary to carry out missions assigned to the command.” Moreover, with regard to unit integrity, it notes that “component forces should remain organized as designed and in the manner accustomed through training to maximize effectiveness. However, if a JFC desires to reorganize component units, it should be done only after careful consultation and coordination with the Service component commander.” At this point, the position of the COMAFFOR as the point of convergence between the operational and administrative branches can become critically important. The COMAFFOR, an expert in the capabilities and limitations of AFFOR, understands the impact that reorganization of the latter will have on their ability to attain operational objectives.

We must realize, though, that ADCON is not exclusive to the COMAFFOR; for attached forces, the home-unit Air Force commander receives a share. For operations as part of an Air Force service component to a joint force, the COMAFFOR holds ADCON authorities over the AFFOR but not total ADCON. The latter includes all actions related to administration and support of service forces from initial accession to final separation for either home-station or deployed functions. As described in AFDD 1 and both the Enabling Concept and its implementing program action directives, those elements of ADCON necessary to prepare and sustain the AFFOR for operational employment should be specified to the COMAFFOR. The home-unit commander retains the remaining elements. For instance, the gaining COMAFFOR normally should have authority and responsibility for providing safe and secure
billeting for deployed forces, but the authority to maintain personnel records and oversee family housing at the home station remains with that station's commander. The elements of ADCON specified to the deployed COMAFFOR and those retained by the home-unit Air Force commander should be spelled out not only in the service G-series orders that establish the expeditionary organization but also in the deployment orders that attach forces to that organization.20

So Who Is in Charge?

Returning to the original question, we can offer a simple answer: the properly designated Air Force commander is in charge of AFFOR. An Air Force commander

• is a service commander within the administrative branch of the chain of command;

• may also be a service commander within the operational branch of the chain of command when assigned or attached to a joint force;

• exercises ADCON to organize, train, equip, sustain, and discipline AFFOR to meet service standards;

• receives service support from the next-higher Air Force commander through the service ADCON chain; and

• responds to orders from the next-higher Air Force commander in the service chain.

In addition to these responsibilities and authorities as an Air Force commander, a COMAFFOR

• is the senior Air Force commander within the operational branch of a designated joint force commander;

• exercises OPCON to employ forces in response to orders from the JFC directly above him or her in the operational branch of the chain of command;
• exercises ADCON to organize, train, equip, sustain, and discipline AFFOR in accordance with Air Force standards and procedures in order to execute the OPCON orders;
• receives service support from the next-higher Air Force commander through the service ADCON chain; and
• responds to ADCON orders from the next-higher Air Force commander in the service chain as long as these orders do not conflict with the OPCON orders from the operational chain.

In the event of a conflict between the two branches, the authority of the operational branch takes priority over that of the administrative branch.

Therefore, whether you are an Air Force commander or a COMAFFOR, you remain responsible for the Airmen under your command and have the requisite authority to carry out that responsibility. You’ve got the stick. Have a great flight.

Notes


3. Note that this article limits itself to the discussion and description of an Air Force commander of Air Force forces; for that reason, it does not address the role and authorities of the joint force air component commander—a joint commander.


8. Ibid., GL-8.
9. Ibid., GL-11.
10. Ibid., IV-3.
11. Ibid., II-9; and AFDD 1, *Air Force Basic Doctrine*, 55.
12. AFFOR C2 EC, 50.
18. Ibid.
19. Ibid., V-18.
20. AFDD 1, *Air Force Basic Doctrine*, 74; and AFFOR C2 EC, 12.

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**Lt Col Brian W. McLean, USAF, Retired**

Mr. McLean (USAF; MA, Old Dominion University) is a doctrine analyst for the Joint and Multinational Doctrine Directorate of the Curtis E. LeMay Center for Doctrine Development and Education, Maxwell AFB, Alabama. He is responsible for analyzing and developing the official Air Force position on the proper integration and use of the service’s forces within a joint or multinational force structure and for advocating that position as the Air Force input to joint and multinational doctrine. He is a widely recognized expert on command relationships and a regular briefer to students at Air War College and to senior Air Force leaders at Capstone, Joint Force Air Component Commander, and Joint Flag Officer Warfighting courses. A master navigator and instructor weapon systems officer, Mr. McLean flew the C-141, F-4, and, on exchange duty with the US Navy, the F-14. His staff assignments included Tactical Air Command, Pacific Air Forces, US European Command, and Headquarters Air Force, with his final assignment as a member of the initial cadre for the stand-up of the Headquarters Air Force Doctrine Center. His Air War College student paper *Joint Training for Night Air Warfare* received the Air Force Historical Foundation’s 1991 Colonel James Cannell Memorial Award for best paper by a Command Sponsored Research Fellow.

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Deployed Communications in an Austere Environment

A Delphi Study

Capt Andrew Soine, USAF
MSgt James Harker, USAF
Dr. Alan R. Heminger
Col Joseph H. Scherrer, USAF

The information and communications technology (ICT) field is undergoing a period of tremendous change. The exponential growth rate of ICT capability in recent decades, which has had an undeniable effect on every aspect of our society, will likely have ramifications for military operations in austere environments. The Air Force’s 689th Combat Communications Wing commissioned a study to forecast the future of mobile ICT in such environments. Researchers at the Air Force Institute of Technology chose to employ the Delphi technique as the methodology for executing this task. The following scenario, based on the results of that study, demonstrates how possible changes in ICT might affect military operations. The article then discusses relevant issues that one would need to address before such possibilities become reality.

The Scenario:
Sometime during the Next 10 to 20 Years
in a Country Wracked by Natural Disaster and Sectarian Strife

The stealthy remotely piloted aircraft (RPA) streaked silently over the valley. If Senior Master Sergeant Riley had blinked, he would have missed it, but he was expecting the aircraft. The sergeant watched in
anticipation as the pointed, narrow cylinder dropped from an opening in the bottom of the platform. The attack drone veered and accelerated towards the north, vanishing before its payload hit the ground.

With perfect precision, the cylinder (not standard ordnance but a radio frequency–satellite communications [RF-SATCOM] network link) hit its mark—the top of the tallest mountain overlooking the valley. This new device supplied cell-phone-like connectivity to each Soldier throughout the area of operations, along with back-haul connectivity to the rest of the Department of Defense’s worldwide communications network. Riley had used the backup system to enter the request only 20 minutes ago, employing a series of linked drones to send a message to the larger staging area about 400 kilometers due north. His team was responsible for securing this valley and setting up the communications infrastructure in preparation for arrival of the main force, which would conduct humanitarian-relief efforts for the local population. The latter had suffered from disastrous flooding and landslides brought about by a stronger than normal monsoon season.

A light began blinking on the small device strapped to Sergeant Riley’s forearm as he walked back into the tent.

“We’re back up,” said Airman First Class Biggs.

“Good. Where are they?”

“About 15 kilometers to the east. Everyone’s vitals are within normal, no injuries. Staff Sergeant Ramirez reports that somebody tried to take a shot but turned tail when they returned the favor. They’re resuming their patrol. I’ll mark it.” Airman Biggs hit a few buttons on his terminal. A moment later, a chorus of beeps arose from inside the tent as everyone’s armband announced to its wearer the alert and subsequent map update. Fifteen kilometers way, Ramirez hit a few keystrokes on his armband. A mortar tube automatically pivoted towards the marked sector should its services be needed.

Riley sighed in relief. The scout patrol had recently reported that it had taken some harassing fire, and then as if on cue, the primary net-
work went down. Several warlords in this part of the country weren't thrilled about their presence, so someone had remotely hacked into the network and introduced a virus that attacked friendly tactical systems. The intelligent security systems had detected the intrusion and deployed countermeasures but not before the primary intratheater link went down. Though internationally banned, those types of technologies somehow still showed up in environments such as these. Riley grinned, wondering if his adversary had his device in his pocket when it suddenly overheated and caught fire.

“Sergeant Riley, Ramirez says his helmet cam caught a glimpse of one of the attackers, but I doubt that these guys are in the system at Langley. I saw this improved ‘hostile or friendly’ app on the net earlier. What we’ve got is tied only to the known hostiles in the system, but this new one can match the pic from Ramirez with anybody in view. If somebody crosses paths with him again, like in the village market, it’ll ‘paint’ him,” offered Biggs.

“Nice. If it’s got more than three out of four stars, go ahead and pull it down,” replied Riley. The online toolbox was a lifesaver, literally. Troops in the field who needed a new capability for any particular situation—or who already had one but needed an upgrade—could just download it from the secure repository practically anywhere on the planet. They could even rate it as a good app or a dud. Riley looked back at Airman Biggs and tried to remember being so young. Biggs really knew his way around this technology stuff, as was usually the case with the younger troops. Obviously a generational thing, they all grew up just expecting it to be there and ready to use. He probably wouldn’t even recognize the Air Force that Riley knew when he was that age: hauling around all that comm equipment that usually did only one thing and oftentimes not all that well; bulky, fuel-hungry generators that advertised your exact location to every jerk with an AK-47 within 100 kilometers; the mountains of batteries that you had to bring in and carry around. . . .
A voice emanating from his armband brought him back to the present. “Sergeant Riley, what's your status?” It was Major Hanson. Located at the staging area, he was conducting final preparations for deployment of the main force.

“Sir, we've had a few hiccups, but nothing serious. We're on schedule, and the equipment is almost ready,” Riley responded.

“Brilliant. We’re bringing a few extra teams for security. Will that be an issue?”

“Shouldn't be, but it might be a good idea to throw on a couple of extra gateways to increase our bandwidth, just in case.” You can never have too much bandwidth, even out here. “A few extra teams” had a wide interpretation; too many heads might start dragging down the local network. Having some cushion ready to go would be nice. Maybe he should ask for another solar power supply as well—after all, they don't take up much room.

While Riley updated the major, the network autonomously uploaded a profile of the attack to the main system at Langley. There, it would analyze the data and push out a patch with updated security algorithms. The entire theater would have immunity within the hour.

**Behind the Scenario**

This story sounds like something out of science fiction. However, according to the Delphi panel that offered input for this research, the technologies it describes may be in place within the next 10 to 20 years—in some cases, perhaps even sooner. A research methodology, the Delphi technique forecasts future possibilities based on expert knowledge of areas relevant to the study. This method “has become a fundamental tool for those in the area of technological forecasting.” In fact, many researchers advocate it for research involving subjects for which a previous datum is unavailable or nonexistent. R. C. Oliver and his colleagues also confirm that “Delphi is best suited for evaluat-
ing the alternatives of some definable although not necessarily narrow issue . . . in which the experience of experts is of particular value.”5 Finally, Somnath Mishra, S. G. Deshmukh, and Prem Vrat’s analysis to match forecasting techniques with specific technologies found the Delphi method a particularly good fit for studies related to information technology.6

The National Defense University has presented four major categories of the ICT industry: hardware, software, information services, and communications. It further divides these categories into sectors such as cable, telecommunications, manufacturing, cellular phones, software, computer and networking hardware, the Internet, data storage, and associated services and applications.7 In the context of its report, the university developed these categories to capture the state of the ICT industry as it presently exists. However, research for this article attempted to address the predicted capabilities of ICT in future states. Certain knowledge areas that would prove useful in generating a forecast—such as trends, revolutionary concepts, and both basic and applied inquiry—did not seem well represented in the existing categories as defined. Therefore, researchers at the Air Force Institute of Technology first examined major categories of the ICT field and derived five general knowledge areas more practical for forecasting future capabilities: concept design and demand, research and intellectual aspects, technology development, application, and, ultimately, employment.

No firm agreement exists on the number of panelists necessary for an effective Delphi.8 On the one hand, Albert P. C. Chan and his colleagues find 10 members an adequate number of panelists to represent a sufficiently wide distribution of opinion.9 On the other hand, some studies show no consistent relationship between panel size and effectiveness.10 Regarding the minimum number of panelists, Jacques Etienne Des Marchais indicates a minimum of six.11 Further, David Boje and J. Keith Murnighan found no effect for group sizes of three, seven, and 11.12
Using the Internet, academic journals, and social networking, the research team developed a list of 100 potential panelists across the five knowledge areas from organizations including academe, non-Air Force governmental organizations, and the private sector. These individuals represented a wide spectrum of involvement within the ICT industry, including concept development, research and development, technology development, application, and the employment of technology. After prioritizing the list with the sponsoring agency, the research team contacted the 25 most desirable candidates, securing the participation of eight experts.

Critics of Delphi cite the difficulty of defining those criteria that make someone an expert. For the purposes of this article, we use V. W. Mitchell's definition of an expert as one who has had a significant amount of involvement within the industry, both past and present. Many studies recommend a minimum of five years of specific experience in the particular industry, which we used as the defining factor of expertise within the ICT industry. All participants have between 20 and 40 years of experience in their field.

Participants on the Delphi panel included a board member of the Association of Professional Futurists who has coauthored books on the future of technology; a program manager in the area of defense electronics, communications, and signal processing; an associate professor of systems engineering specializing in information operations, mission assurance, computer and network security, quantum cryptography and information, and mission-impact assessment; a director of business development and sales for a major satellite communications group, specializing in deployable communications; a practice leader specializing in telecommunications, innovation science, and operations management who has worked at major research facilities; a chief software architect and development lead at a technology consulting group; a disaster-communications engineer at a major networking corporation; and a federal government professional in emergency response to information-technology disasters.
Although the scenario is based on the forecast developed by the Delphi panel, the latter did not create it. Rather, the authors developed the scenario to illustrate how the ideas presented in the forecast could affect the use of deployed communications in the near future. The following discussion explores issues included in the scenario that highlight changes we may expect to see in such communications during the coming years.

**Bandwidth**

The RF-SATCOM network link dropped from the RPA signifies one of the trends among the panelists' forecasts. As ICT evolves, despite evolutions in protocols and data-compression techniques, bandwidth requirements will continue to grow—possibly at an exponential rate. The panelists suggested that the increase in bandwidth needs stems from expanded data exchange among robots, sensors, RPAs, and personal ICT devices such as smartphones and tablets. Therefore, as we move into future engagements, the availability of usable bandwidth providing gateways to access the Global Information Grid (GIG) will escalate dramatically. The ability simply to “deploy” a unit similar to the RF-SATCOM network link in an unforgiving environment as a means of facilitating near-instant accessibility to data exchange will likely increase virtually all aspects of the campaign it supports, whether a humanitarian-relief effort in Haiti or terrorist suppression in Africa.

**Satellites versus Alternatives**

The experts had divergent views on how deployed communications systems would link back to the GIG. The scenario uses both projected technologies. First, the self-configuring RF-SATCOM network link acts as a gateway to the GIG, providing wireless RF connectivity to authorized devices within the area of operations. As described by the panelists, some austere locations create great difficulties for a direct satellite link. For instance, locations under high foliage, such as a jungle environment, as well as those inside hardened shelters and under water
render satellites less effective. Other panelists envisioned highly mobile data links in the form of RPA relay systems. In the scenario, Sergeant Riley uses this as a temporary communications medium to request the more robust satellite-link back-haul system.

**Personal Information and Communications Technology**

As devices and applications converge into smaller, faster, and cheaper individual computing devices, their interfaces will evolve. The interaction will become more fluid as the interfacing experience begins to transform to sensory inputs, biological queues, and eventually human-enhancement implants. Sergeant Ramirez communicates with Airman Biggs with a device similar to current smartphones, but it also monitors his vitals via a few nonintrusive biological sensors capable of immediately alerting both the wearer and nearby allied forces if any readings fall outside a predetermined threshold. Additionally, thanks to the fact that the RF-SATCOM network link offers local device-to-device communications, the dissemination of mission-critical information and supporting data now takes place in real time—as occurred when Airman Biggs sent an alert and map update throughout the unit. This update warns friendly forces about hostiles nearby and allows Sergeant Ramirez to coordinate retaliatory fire from isolated locations, enhancing both his unit’s safety and combat effectiveness. The sergeant captures and processes photos, using them to query and update the remote database. This ability signifies two possibilities. First, it underscores the necessity of global connectivity to send data to troops in rugged locations. Second, it illustrates possible advantages of an application repository providing real-time access and updates to mission-support software. According to the panelists, multiple commercial entities have already successfully implemented similar corporate repositories.

**Power**

The panelists also considered the powering of ICT devices, identifying power generation, storage, and distribution as areas of concern. In the
scenario, Sergeant Riley reminisces about deployed forces relying exclusively on petroleum-based power generation and replaceable batteries. The panelists forecast that power generation will slowly change from current methods to technologies such as fuel cells and locally developed power that uses renewable methods such as wind, water, and sunlight. Such renewability is beneficial from more than simply an environmental standpoint. Currently, the power needed to run a forward operating base demands many fuel generators, which leave a large footprint. Additionally, the fact that generators require fuel and maintenance adds to the logistics burden. Local renewable energy sources would drastically reduce the number of support personnel and demands for supply. Power storage and distribution converged in this scenario when the sergeant thought to request another solar power supply. Panelists suggested that the incremental battery improvements, combined with personal ICT evolution that lowers power consumption, will extend ICT battery life substantially. Members of the panel suggested wireless power distribution but acknowledged that it might not be feasible in the near-to-moderate future due to radio interference and health-related risks.

**Security**

The panelists forecast that as our networks become more modular and based on Internet protocol, devices would become more autonomous—witness the part of the scenario when the network pushes the attack profile to Langley for automated analysis and creation of a security patch. However, some panelists cautioned that because these modular network devices may be engineered, manufactured, and programmed for autonomy outside the Department of Defense, one must consider possible security risks akin to “backdoor computing” (bypassing normal authentication and thus securing illegal remote access to a computer). The panelists concurred that data security will be a concern in the distant future. As ICT evolves, so will malicious attackers; furthermore, as personal ICT proliferates, becoming less expensive and more ubiquitous, the pool of potential attackers will grow in step with it.
The Way Ahead

It seems naïve to assume that humankind will continue to conduct traditional warfare even as ICT developments prompt new operational capabilities and demands. Instead, we should attempt to envision how the latter will improve operations. Commentary from the eight experienced ICT industry experts yielded the common trends identified and discussed above. Bandwidth requirements will increase rapidly, and back-haul systems linking forward operating locations to the GIG will develop. Satellite capabilities will multiply, just as alternatives and RPA-relayed mediums will emerge. Personal ICT devices will progress and proliferate. The convergence of applications and data services on these devices will decrease the number of tasks that they cannot perform. As power techniques develop, a “charged” device will operate substantially longer before depleting its power source. In terms of security, human nature creates a continuous, reciprocal battle of measure/countermeasure/countercountermeasure, and so forth. An interesting perspective to consider is that the forecasts we used to produce this scenario did not specify particular developments or actual capabilities; rather, they identified distinct trends and likely paths of ICT evolution. Through this perspective we can apply these trends not as a specified plan of action but as a planning tool designed to gain and maintain adversarial advantages. As President Dwight D. Eisenhower declared, “Plans are nothing; planning is everything.”

Notes


Capt Andrew Soine, USAF
Captain Soine (BS, Louisiana Tech University; MS, Air Force Institute of Technology) is a program manager with the Manufacturing and Industrial Technologies Division, Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson AFB, Ohio. He is responsible for planning, managing, and executing programs that provide advanced manufacturing processes, techniques, and technologies for timely, high-quality, and economical production and sustainment to strengthen the defense industrial base under the Title III program of the Office of the Secretary of Defense’s Defense Production Act. He also addresses Air Force systems through the service’s ManTech program. Captain Soine previously served in the Space Development and Test Directorate, Kirtland AFB, New Mexico; the 580th Aircraft Sustainment Group, Warner-Robins Air Logistics Center, Georgia; and as air and ground movement officer in charge with the US Army Corps of Engineers, Afghanistan Engineer District, Kabul, Afghanistan.

MSgt James Harker, USAF
Master Sergeant Harker (BS, New York Institute of Technology; MS, Air Force Institute of Technology) is the wing deployment manager for the 689th Combat Communications Wing, Robins AFB, Georgia. He is responsible for ensuring the combat readiness of equipment valued at $460 million and 1,500 Airmen from 10 squadrons composing two groups. Master Sergeant Harker has managed several work centers charged with various functions, including the maintenance of security systems that guard nuclear assets and the dissemination of Armed Forces Network radio and television broadcasts to their intended audiences. He also completed a special-duty assignment as an academy military trainer at the United States Air Force Academy, where he introduced cadets to the enlisted perspective and facilitated their development as future leaders.
Dr. Alan R. Heminger
Dr. Heminger (BA, University of Michigan; MS, California State University–East Bay; PhD, University of Arizona) is an associate professor of management information systems at the Air Force Institute of Technology, Department of Systems Engineering and Management. He has a background in networked collaborative work systems, strategic information management, and business process improvement. Dr. Heminger has undertaken research and consulting for Air Force and Department of Defense agencies, including Air Force Material Command, the Air Force Research Laboratory, the Air Force Center for Systems Engineering, Air Force Special Operations Command, the Air Force Office of the Chief Information Officer, the Air Force Communications and Information Center, the Defense Threat Reduction Agency, the 689th Combat Communications Wing, and the Defense Ammunition Center.

Col Joseph H. Scherrer, USAF
Colonel Scherrer (BSEE, Washington University in Saint Louis; MBA, Boston University; MS, Air Force Institute of Technology; MA, Naval War College; MA, Air War College) is commander of the 689th Combat Communications Wing, Robins AFB, Georgia. He leads 1,500 duty Airmen in an expeditionary cyber operations mission that deploys combat communications and air traffic control as well as landing-systems capabilities in permissive and nonpermissive contingency environments. A distinguished graduate of the Air Force Reserve Officer Training Corps program, Air Force Institute of Technology, Advanced Communications Officer Training School, Naval War College, and Air War College, Colonel Scherrer is the coauthor (with Lt Col William C. Grund) of A Cyberspace Command and Control Model (Maxwell Paper no. 47, 2009). He has participated in several theater operations, including Deny Flight, Provide Promise, Joint Forge, Deliberate Force, Southern Watch, and Enduring Freedom. He has commanded a cyber wing, a mission support group, and three communications squadrons. Colonel Scherrer has served in a variety of engineering, fixed communications, tactical communications, and staff assignments, including the Joint Staff, where he authored the Department of Defense’s first national military strategy for cyberspace operations.

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Recent operational successes with new space-based capabilities offer important reminders of our dedication to a strong space program for national security. Our military and intelligence operational responsibilities worldwide demand timely intelligence, surveillance, reconnaissance, warning, and communications to maximize the effectiveness and efficiency of the force. Investments in research, development, production, and operations have yielded important space-based mission capabilities that differentiate the United States and its allies in the execution of national security objectives.

The dependence of US national security on space continues to grow. A drumbeat of studies, reviews, speeches, articles, and congressional testimony, however, carries a clear message: (1) US national security space systems cost too much and take too long to go from concept refinement to deployment; (2) threats to our space capabilities are significant and increasing—if left unaddressed, our space infrastructure will become more vulnerable, fragile, and indefensible; and (3) the current US financial situation, including potentially draconian defense cuts, challenges the continuation of status quo acquisitions.

This article seeks to realistically address documented risks associated with a rapid transition from baseline space-program architectures if that transition involves immature technology alternatives. It draws on past Government Accountability Office (GAO) reports, studies, and program histories to raise awareness of the significant threats to successful operations and program acquisition when architectural transition decisions rely on unproven design and limited understanding of the ability and cost of production. The article includes direct reference
to overhead persistent infrared (OPIR) architectural-transition concepts currently under consideration with the advent of disaggregation approaches by the Space and Missile Center. Initial concepts introduced by the center include changing from the space-based infrared system (SBIRS) to a wide field of view (WFOV) disaggregated approach.¹ This article recommends a judicious, low-risk demonstration and prototyping approach to insert capability, retire risk, and realize enhanced estimation of production and manufacturing costs.

**Reinventing Space**

Recently, Air Force leaders have made efforts to explore new architectures and acquisition strategies as potential solutions to the perceived high cost of continuing legacy space programs. Today most of the service's constellations consist of a few large, highly capable (typically multimission) spacecraft. Specifically, these new candidate architectures advocate the distribution of mission capabilities onto a variety of platforms—commercial or smaller, purpose-built craft. This concept, termed *disaggregation*, urges the United States to “buy capabilities in smaller capacity increments, distributed across more but smaller satellites or hosted payloads, and migrate ground segments to (shared), modular, open architectures.”² Interestingly, OPIR already represents a disaggregated architecture that uses multiple, different orbits; free-flying and hosted payloads; and a distributed ground architecture to support a number of mission users. Is the national security community ready to begin such an extensive and, some would say, radical transition to additional new architectural- and capability-procurement approaches—especially when one considers that our current systems are just beginning to demonstrate significantly enhanced performance and functionality beyond expectation?³

Although the OPIR mission area has existed for decades as overhead nonimaging infrared with SBIRS and other systems, it is now the new kid on the block, integrating target-signature nuances, time, and place into persistent intelligence and operational products that bring exciting
capabilities to the war fighter. The timely, near-seamless integration of observations provides discriminating capabilities. Users, now responding with analytic tools and techniques to best exploit the new capabilities, are only beginning to understand how to utilize the amazing new data. Having recently tested the downloading of OPIR sensor data directly to handheld devices to enhance battlespace awareness, the Army wants to pursue additional experimentation under the proposed Joint Capability Technology Demonstration. Furthermore, the SBIRS Program Office is pursuing use of SBIRS infrared data to support requirements for weather and climate information.

Expanding Overhead Persistent Infrared’s Sensor Capabilities

The Alternative Infrared Satellite System (AIRSS), a new program started in the Department of Defense’s (DOD) budget for fiscal year 2007, was intended to substitute for the geosynchronous Earth orbit (GEO) satellite segment of the SBIRS High program and produce a replacement for the US Defense Support Program’s (DSP) missile-warning satellites. According to a GAO report of 2007, the DOD was not pursuing the AIRSS as a “plan B” program as originally envisioned. Rather than seek to maintain continuity of operations, the program focused on advancing capabilities. Moreover, it did so within highly compressed time frames. DOD stakeholders disagreed regarding the wisdom of this approach, given past experiences with space acquisitions.

The current Commercially Hosted Infrared Payload (CHIRP) experiment derives from the AIRSS program, also known as third-generation infrared surveillance legacy. Upon termination of the latter, the Operationally Responsive Space Office and SBIRS Program Office continued work on the hosted flight demonstration to advance process development of hosted payloads and conduct on-orbit testing of the CHIRP focal plane array at the least cost. Science Applications International Corporation’s WFOV sensor is integrated on the SES-2 commercial geo-
synchronous communications satellite built by Orbital Sciences Corporation to validate missile-warning technologies from GEO in a fast and cost-effective manner. The CHIRP sensor features a fixed telescope that can view one-quarter of the earth from GEO. The infrared sensor will test the potential of its WFOV capabilities for future OPIR missions for the Air Force.

The ongoing WFOV demonstration encompassed by the CHIRP experiment helps to retire risk associated with incorporation of WFOV technology into missile-warning architectures and informs us of issues in the commercial hosting of payloads. However, it represents only a first step toward addressing the many performance, architectural, and manufacturing feasibility risks identified in numerous acquisition reviews. Transitioning from the SBIRS architecture that must meet demands across a number of mission areas—missile warning, missile defense, battlespace awareness, and technical intelligence—to a new, disaggregated architecture that will rely principally on WFOV technology carries significant mission risk at this time.

The CHIRP WFOV missile-warning (evaluation) sensor leveraged limited new-sensor focal-plane-array chip-production capabilities derived from the AIRSS program. A recently completed Burdeshaw Associates study of sensor performance notes that these WFOV designs contemplate use of large format staring arrays to provide full earth disk coverage in a series of optical payloads without dynamically adjusting the optical path. The stated, but unproven, advantage to the WFOV design paradigm is in reducing complexity, and therefore cost, through:

- Elimination of an optical path element such as the mirror assembly
- Elimination of moving mechanisms
- Elimination of ground tasking software for the moving mechanisms
- Use of commonly available optics for low(er) cost telescopes.

The expanding missions in OPIR demonstrate the need for precise geolocation performance. Since the performance necessary to meet mission requirements depends upon position knowledge of all payloads so they operate as one, the latter drives integration precision,
spacecraft stability, ephemeris, and line-of-sight knowledge. As a consequence of this complexity, these design parameters must also accommodate overlapping of the coverage of independent sensor payloads in order to interleave pixels to meet mission demands for geospatial resolution. Plans for the CHIRP experiment did not include validation for this criterion. The fundamental technology upon which WFOV uniquely depends—large-format, high-pixel-count infrared focal planes with thousands of pixels per side—is still maturing in uniformity and defect rates relative to the stringent target-detection needs of missile warning and the other OPIR missions.

Current WFOV sensor alternatives are under consideration as a payload that can be either hosted by or deployed on a small satellite. The coverage capability expands by integrating a focal plane array that contains 3,000 by 3,000 detectors (3K x 3K focal plane array) in combination with various optics options from four degrees to 14 degrees. By using such options, the focal plane array can observe greater geographic areas. However, the expanded coverage areas result in less geospatial resolution because as coverage increases, resolution suffers, adversely affecting the ability to discriminate individual launches from closely spaced launch locations until sufficient separation of the trajectory occurs. The strategic and theater components of the OPIR missile-warning requirements assess raid-counting accuracy and complete understanding of the boost-phase track as an imperative to quickly warn of and characterize an inbound attack to support responsive decision making. These design trades are important in determining system performance. The Burdeshaw Associates study reveals that

- WFOV is desirable technology, but the remaining design and production challenges preclude near term proven technology availability. The present sensitivity provided by these designs may be insufficient for current upper stage threats and many emerging threats.
- Affordable uniformity and defect rates in large medium wave infrared (MWIR) formats is still a work in progress.
- The wide field coverage combined with available large format focal planes limits the aperture size to those much smaller than SBIRS.
Simply stated, sensitivity requires photons, and the number of photons is a function of aperture size.

- Separation and counting of targets in realistic scenarios is poor and a real concern.

To help improve target discrimination, the WFOV designs have added a moving filter wheel to the optical path to accommodate additional infrared spectral bands. This increases complexity and cost over a CHIRP-like staring array.\(^9\)

Some realities of WFOV payload integration with host vehicles may call for additional technology and engineering. The Burdeshaw Associates study draws from a survey of industrial-base analyses which conclude that

- WFOV may need to add image motion compensation mirrors in the optical path to retain image quality due to spacecraft bus vibrations, stability and drift characteristics that would otherwise spoil the optical image and its registration necessary for the success of imaging processing techniques and geolocation.
- The relatively slender WFOV multi-telescope designs will need a sufficiently stiff integrating structure to transfer attitude reference from telescope to telescope to maintain micro-radian level absolute bore-sight knowledge potentially precluding lower cost commodity bus options.
- An internal self contained line of sight knowledge calibration capability will be an essential part of WFOV payload design maturity.
- A thermal, solar and sun outage protection design must be completed to mature WFOV payload design. This is a special challenge for hosted WFOV payloads where CONOPS [concept of operations] flexibility may be restricted by primary commercial mission priority.\(^10\)

The WFOV designs must address these complexities early in the acquisition to assure a smooth, predictable transition to the new technology.

Staff assessments by the Office of the Secretary of Defense conclude that required functional availability precludes transition from SBIRS prior to procurement of SBIRS spacecraft GEO 6 due to the alternative development timelines. Thus, meeting the need date for SBIRS GEO 7—assuming a new start in fiscal year 2014—involves risk. In today’s fiscal climate, the Office of the Secretary of Defense is struggling with
simultaneously pursuing a new architecture while completing/sustain-
ing its current missile-warning architecture. Unlike the decision dur-
ing the 1990s to transition from the DSP—the previous OPIR spacecraft
used for missile-warning detection—to SBIRS, no stored DSP or SBIRS
spacecraft are available to reduce operational hazards should acquisi-
tion delays, performance failures, or launch disasters delay successful
new architectural deployments. Comparing the present situation with
the one in 1994 is revealing:

• In 1994 the missile-warning architecture was very robust with
  more than 20 years of sustained DSP operations, spares on orbit,
  and six more satellites (DSP 18–23) in production, resulting in low
  operational risk and time to design and develop SBIRS.

• Presently the missile-warning architecture reflects declining
  health of remaining DSP satellites, a single SBIRS GEO 1 space-
craft on orbit, and SBIRS GEO 2–4 in production, reflecting far less
  architectural robustness.

Moreover, acquisition history has repeatedly demonstrated that cost
assessments of revolutionary alternative architectures are generally
quite optimistic due to frequent underestimation of systems engineer-
ing, program management, nonrecurring engineering, operational in-
tegration, and launch operations. The cost of ground infrastructure is
often assumed neutral among alternatives. In this case, however, dis-
aggregated architectures requiring large numbers of sensor hosts will
surface new and possibly unexpected problems in management, infra-
structure, and data integration.

**Possible Profile of a Low-Risk Augmentation Program**

Over the last several decades, we have learned many painful lessons
concerning space system development (SBIRS, the Transformational
Communications Satellite, space-based radar, etc.), probably the most
significant of which concerns the critical nature of mature technology.
Transitioning new technologies into comprehensive acquisition pro-
grams favors diligent early efforts to demonstrate the performance of those technologies and to evolve toward a full prototype prior to commitment to full production programs. This circumstance appears very relevant to OPIR WFOV alternatives.

Consequently, we need a structured approach that reduces the likelihood of both performance problems and schedule delays through judicious, step-by-step demonstration of individual spacecraft development, production, and performance as well as multispacecraft architectural performance and impact. Key elements of that approach should include (1) sustaining the operational mission of foundational capability throughout transition, (2) fully assessing the operational performance of new technology during transition from demonstrator to prototype, (3) validating final operational performance and production costs during prototype development, and (4) understanding architectural implications.

Figure 1 depicts a structured serial approach that minimizes costs through the transition while retiring performance, production, and manufacturing pitfalls. The Burdeshaw Associates study offers an example of the schedule and elements associated with a low-risk maturation program leading to an architectural alternative and/or follow-on. The dark blue and green arrows reflect SBIRS spacecraft already in production; the light blue arrows reflect those spacecraft that need additional funding and the estimated dates for delivery to mitigate operational degradation to the mission. The figure shows the three phases of the alternative augmentation technology program, indicating development and production as clear boxes and on-orbit evaluation timelines as red, yellow, and green boxes. The star represents the study's first estimate of a decision point for moving to a new missile-warning architecture.
Figure 1. Profile of a low-risk augmentation program

Sustain Operational Mission throughout Transition

Fortunately, SBIRS performance is exceeding expectations. We understand its costs and risks of production; further, with the procurement of SBIRS GEO 7 and 8 and highly elliptical Earth orbit (HEO) 5 and 6, we can expect that sustained capability will support all four mission areas through 2030. This offers the DOD a sustained period during which it can thoroughly evaluate and develop WFOV capabilities and follow a minimal annual investment approach to reduce midterm and long-term risk. By maturing the mission requirements of the WFOV constellation, technical capability, and architectural approach, the department can reach a transition point based upon comprehensive understanding of the cost, performance, and ability to produce and manufacture the new components of the alternative architecture. Steps toward realizing that end begin with fully understanding and certifying
across the community of stakeholders the intended set of demands that the proposed WFOV architecture will address.

**Fully Assess Operational Performance of New Technology during Transition from Demonstrator to Prototype**

The current CHIRP demonstration emphasizes assessing the validity of WFOV-expected simulations conducted during research, development, test, and evaluation (RDT&E) of third-generation infrared surveillance; additionally, it provides a baseline understanding of the basic performance of WFOV and integration of the payload on a commercial host. Evaluating test results over eight months to one year will help determine data accuracy and application of the WFOV sensor for missile-warning augmentation in the future. As discussed before, numerous data acquisition and processing areas need to be addressed as a means of determining whether the data acquisition and accuracies are sufficient to support missile-warning missions, both strategic and tactical. To validate data-accuracy capabilities, we will probably need a follow-on multisensor technology demonstration.

After establishment of performance requirements, sensitivity, WFOV uniformity, and defect rates, technology demonstration can move from validating expected performance of the WFOV technology to design demonstrations that more closely examine the specific mission-performance demands that the DOD assigns to the missile-warning augmentation capability. If augmentation is really intended to concentrate on enhancing resiliency of the most critical OPIR mission needs, then we should direct overall mission performance toward sustaining strategic and theater missile-warning capabilities through any contingency. We must demonstrate performance that supplies sufficiently accurate information to address missile warning through all threat environments across all geospatial areas. The architecture should focus on resiliency sufficient to survive a nuclear environment to the extent that other strategic forces can endure. To enhance the flexibility of the architecture, we must demonstrate WFOV sensor configurations that
will extend the area coverage from one-quarter to full coverage of the earth, just as we must stiffen the bus and process multiple arrays together to ensure the accuracies necessary for OPIR missions. Moreover, we must deal with extended on-orbit satellite and sensor-life demonstration since replacement of short-life spacecraft or sensors for large, long-lived constellations significantly increases the life-cycle costs associated with providing the mission capability over time. After the demonstration of design technologies, missile-warning augmentation should move to the expected demonstration of an operational design configuration for the multisatellite prototype.

**Validate Final Operational Performance and Production Costs during Prototype Development**

Once final design for the missile-warning augmentation capability matures, we should pursue near-final-design prototypes to validate production and manufacturing costs and to develop production-line and supplier-tier organizations, processes, and costs. On-orbit assessment of multisatellite performance against near-standard designs will enable high-confidence understanding of constellation mission capability and substantiate the overall concept of deployment and operations. Additionally, confidence of the broader industrial base in estimates of production cost will assure the sustainment of program expenses throughout longer production runs of numerous satellites. High-confidence estimates of program costs will enable the definition of more realistic life-cycle costs for the entire architecture, thus enabling a better-informed transition decision.

**Understand the Architectural Implications**

Finally, this low-risk approach gives us time to fully understand the entire architectural evolution (including ground) costs associated with transition to a “disaggregated architecture” of numerous individual spacecraft—both free flyers and hosted. Changes in operational concept and force management will have time to adapt to new ways of do-
ing business. Understanding related costs for launch infrastructure, communications upgrades, mission management, mission data processing across many more systems, and mission-processing changes will all mature as the sensor and spacecraft design develops.

Acquisition History
Reinforces Concern over Rapid Transitions

A number of reviews of space acquisition conclude that recurring risks continue to plague new starts of space programs and represent acquisition conditions that eventually lead to increases in program cost and unstable program-capability transitions. On 21 March 2012, Cristina T. Chaplain, GAO’s director of Acquisition and Sourcing Management, testified before the US Senate Subcommittee on Strategic Forces, Committee on Armed Services, that our past work has identified a number of causes of acquisition problems, but several consistently stand out. At a higher level, DOD has tended to start more weapon programs than is affordable, creating a competition for funding that focuses on advocacy at the expense of realism and sound management. DOD has also tended to start its space programs before it has the assurance that the capabilities it is pursuing can be achieved within available resources and time constraints. There is no way to accurately estimate how long it would take to design, develop, and build a satellite system when critical technologies planned for that system are still in relatively early stages of discovery and invention. Finally, programs have historically attempted to satisfy all requirements in a single step, regardless of the design challenges or the maturity of the technologies necessary to achieve the full capability. DOD’s preference to make larger, complex satellites that perform a multitude of missions has stretched technology challenges beyond current capabilities in some cases. Figure 2 illustrates the negative influences that can cause programs to fail.11
Similarly, in 2011 a National Defense Research Institute analysis of the root causes of recent breaches of the Nunn-McCurdy Amendment, designed to curb cost increases in weapons procurement, led RAND to identify the following lessons learned:

- Production delays increase exposure to changing private sector market conditions, which can result in cost growth.
- Acquisition flexibility (e.g., start-stop programs) comes with a cost.
- Cost estimates should be conducted independently of a program manager.
- Combining remanufactured and new build items causes complexity and can lead to cost growth.
- Greater planning of manufacturing process organization is required.
- Large reductions in procurement quantities can significantly increase per unit cost.
- Sufficient RDT&E is required to ensure the “produce-ability” of a program.
- Greater government oversight of the contractor is required in a technologically complex project.
- More “hedges” against risky elements of program are required.
- Additional collaboration is needed on design specifications and discussion of cost-performance trade-offs.12
None of this is new. The scar tissue of experience needs to inform the debate. Some of the proposed technologies under consideration as keystones for attaining disaggregated architectures have only just begun technology demonstrations to evaluate their performance capabilities, architectural implications (e.g., reduction of risk to individual nodes and mission network operation), and manufacturing/product feasibility. When only PowerPoint designs represent the extent of capability understanding, significant hazards remain that call for additional research and development and demonstrations to retire risk areas sufficiently to meet mission assurance needs. Structuring an affordable, time-sequenced approach toward retiring these problems will put into place the “hedges” to assure that we avoid unexpected program costs and realize expected performance within the larger architecture.

The complex DOD acquisition process has numerous stakeholders, complicated interrelationships among players, and inextricably linked, interdependent processes. Unsurprisingly, then, as program proposals transition from RDT&E demonstrations to full development and production, a host of new organizational structures, management processes, new personnel, and facility and equipment investment comes into play. The history of cost estimates made in response to requests for proposals suggests that those based on mature, well-known processes and structures are consistently more accurate than those based on fresh or untried approaches. Any assessment of risk during this transition should pay particular attention to the following areas of concern.

**Control Requirements**

With respect to OPIR, clear identification of the requirements subset that an augmentation program should provide will preclude confusion during transition to development and production. Clearly, the current demonstrated WFOV capabilities will not satisfy the full set of OPIR needs. Concentrating on the subset of requirements that such systems will augment alleviates requirements creep as the program progresses; it also hedges against the instability of program costs.
**Improve Systems Engineering**

The slow development of conceptual design by means of progressively more capable demonstrators builds better understanding of performance reliability, architectural integration, and manufacturing/production process costs. Structuring a low production rate allows time to evolve and adapt design and production processes incrementally so that design and production surprises do not result in major increases in program costs and schedule risks driven by operational imperatives.

Similar lessons apply to space systems and the transition from one space architecture to the next. To assure the retirement of similar risks to manufacturing feasibility, we must assure additional evolution from sensor and spacecraft demonstrators to prototypes. In the case of OPIR, the architectural implications of multisensory data integration and interleaving necessitate the testing of multi-WFOV sensors on-orbit to better comprehend the implications for data accuracy and fulfillment of the mission. Until we contend with such demonstrations and prototypes, the alternative architectures remain at high risk for the growth of program costs and possible mission failure.

**Recognize Hidden Costs in Using the Commercial Base**

The RAND study concluded that

the broader lesson learned for this [Wideband Gapfiller Satellite] program is that when DoD procurement piggybacks on a commercial base, notably the commercial base of a particular company and its ecosystem, it takes a certain risk. The base may shrink, leaving it with less capacity to cover total overhead costs. Even if the base does not shrink, it will evolve. If DoD requirements do not evolve in parallel—and there is no inherent reason why they should—the divergence between DoD’s requirements and the market’s requirements means that either the requirements are compromised (admittedly, this may be acceptable in some circumstances) or, eventually, such programs have to stand on their own feet. . . . This suggests that a certain procurement discipline is called for, or DoD will pay the difference. Start-stop programs are costlier than steady-state programs (i.e., when buys are consistent from one year to the next), which, in turn,
are somewhat more costly than total buy programs (e.g., we want six satellites, deliver them when you finish them). Although DoD cannot necessarily commit to even procurements for a variety of reasons (e.g., changing requirements, risk management, congressional politics), everyone concerned should understand that there are costs entailed in maximizing acquisition flexibility.\(^\text{13}\)

**Understand Changes in Procurement Quantities**

Furthermore, according to the RAND study,

Changes in quantity are never the primary source of a change in cost. Rather, quantity changes are always driven by some other factor, such as a change in threat or mission, which changes the requirement, or technical problems, which increase costs and therefore affect affordability.

The initial reductions in planned quantities from the 32-ship class originally envisioned for [the] DD-21 [destroyer] to the ten ships included in the Milestone B baseline were due to affordability. As the system design matured and experience was gained with the key technologies and sub-systems through the EDMs [engineering design modifications], more realistic (higher) cost estimates were developed, which reduced both the production rate (number of ships approved for construction in a given year) and total quantity.\(^\text{14}\)

The current state of Earth coverage by the WFOV focal plane array will likely entail multiple sensors and spacecraft to offer coverage comparable to that of SBIRS. Because of this criterion and the imperative of enlarging constellation size to add a degree of resilience, architectural quantities will increase to 20 or more platforms. Should costs escalate in the transition from demonstration design to system-development decision, the effect on the DD-21 and other programs will likely apply in the missile-warning area as well. This risk again argues for a judicious demonstration and prototyping cycle to allow our understanding of design, performance, architectural, and production costs to mature.
Conclusion

Over the past few decades, Congress has paid particular attention to the DOD's program-acquisition difficulties and has repeatedly directed that both internal DOD reports as well as those by the GAO and various commissions review space and nonspace acquisition programs and practices. Those findings reinforce the need for a judicious development of technology together with incremental improvement and testing of designs prior to production commitment. In today's fiscal climate, setting aside these lessons to once again pursue an architectural transition based upon immature assessments of new technology performance and the ability to produce would be sheer folly. Furthermore, the consequences of delay or cost risks could prove operationally catastrophic for the missile-warning mission because, unlike previous circumstances, we lack a robust backup OPIR mission force structure that can sustain program disruptions.

Notes


6. SBIRS features a mix of four GEO satellites, two highly elliptical Earth orbit (HEO) payloads, and associated ground hardware and software, with dramatically improved sensor flexibility and sensitivity. Like its predecessor, SBIRS has sensors that cover shortwave infrared, expanded midwave infrared, and see-to-the-ground bands, allowing it to perform a broader set of missions than the DSP’s. The HEO sensor configuration includes the following: an infrared payload of about 500 pounds (scanning sensor), three colors (shortwave,
midwave, and see-to-ground), sensor chip assemblies, Short Schmidt telescopes with dual optical pointing, agile precision gimbal pointing and control, passive thermal cooling, 100 Mbps data rate to ground, and strategic and theater surveillance. The GEO spacecraft configuration includes the following: predicted wet weight of about 10,000 pounds at launch; three axes stabilized with 0.05 degrees of pointing accuracy and solar flyer attitude control; RH-32 radiation-hardened, single-board computers with reloadable flight software; approximately 2,800 watts generated by GaAs solar arrays; Global Positioning System receiver with Selected Availability Secure Anti-Spoof Module; infrared payload of about 1,000 pounds (scanning and staring sensors); three colors (shortwave, midwave, and see-to-ground); sensor chip assemblies; Short Schmidt telescopes with dual optical pointing; agile precision pointing and control; passive thermal cooling; and secure communications links for normal, survivable, and endurable operations.


9. Ibid., 151n3.

10. Ibid.


13. Ibid., 84.

14. Ibid., 27.
Jeffrey K. Harris

Mr. Harris (BS, Rochester Institute of Technology), the chief executive of JKH Consulting, LLC, has contributed to US national security capabilities in both government and industry where he has fostered new technologies and programs. He retired from Lockheed Martin as a corporate officer and served as president of Lockheed Martin Missiles and Space and of Lockheed Martin Special Programs. He also served as president of Space Imaging, the first company to provide high-resolution satellite imagery and information products for cost-effective solutions to global business needs. Before entering the private sector, Mr. Harris held senior national leadership positions, including assistant secretary of the Air Force for space, director of the National Reconnaissance Office, and associate executive director of the intelligence community. In all of these capacities, he provided direct support to both the secretary of defense and the director of central intelligence.

Gilbert Siegert

Mr. Siegert (BS, University of California–Santa Barbara; MBA, University of Wyoming) possesses more than 41 years of Department of Defense (DOD) and corporate aerospace experience in many of the space operations and systems that emerged during that period. He has 26 years of experience in the US Air Force, retiring as a colonel; 14 years in supporting the Office of the Secretary of Defense; and several years serving as the president of Space Ventures Consulting. During this consulting period, he worked for Burdeshaw Associates on numerous space-related projects. His expertise in space policy and strategy development, space program oversight, US government processes, and commercial space efforts contributed to the evolution of space operations over the last 40 years. While serving as a special assistant for space policy, strategy, and plans in the Office of the Deputy Assistant Secretary of Defense for Space Policy, Mr. Siegert was called upon to lead and participate in numerous congressional reports as well as interagency and DOD studies and analyses that directly resulted in organizational, program, and force-structure changes over the years. His analysis and inputs formed the basis for the space portion of the past several Quadrennial Defense Reviews and both Space Posture Reviews. He contributed to many of the foundational assessments that led to the Global Positioning System, various military satellite communication systems, space-based infrared system, electro-optical reconnaissance system, space-based radar, missile defense systems, Defense Support System program, multiple space launch vehicles, space situational awareness capabilities, and supporting technologies. Mr. Siegert’s investigation of future commercial space capabilities such as commercial space launch ventures, space solar power generation technologies, space debris generation and domain consequences, and space traffic management concepts enabled him to contribute to space industry projections and industrial base analyses.

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